**W9132T-05-R-0028**

# NAS Keflavik – Keflavik International Airport
# PEM Demonstration Project
# Midterm Project Report

Proton Exchange Membrane (PEM) Fuel Cell Demonstration
Of Domestically Produced PEM Fuel Cells in Military Facilities

US Army Corps of Engineers
Engineer Research and Development Center
Construction Engineering Research Laboratory
Broad Agency Announcement CERL-BAA-FY04

**Headquarters:**

1080 Holcomb Bridge Rd
Suite 100-175
Roswell, GA 30076
Ph (770) 650-6388

**Keflavik International Airport**
**Keflavik, Iceland**

**September 8, 2006**

**California:**

5680 Adobe Road
29 Palms, CA 92277
Ph (760) 367-5005

## Executive Summary

Under terms of its FY'04 DOD PEM Demonstration Contract with ERDC/CERL, LOGANEnergy has installed and operates a Plug Power Gencore 5kWe auxiliary fuel cell power plant (see Appendix section 1) at the Leifur Eríksson Air Terminal at the Keflavik International Airport in Keflavik, Iceland.

The Keflavik Airport is a major stopping point between North America and Europe as well as a vacation destination in its own right. The airport served 1.6 million passengers in 2004. The hydrogen powered unit is electrically configured to provide DC electricity to a simulated DC bus. This DC bus is made up of DC lighting that performs two functions, the first of which lights up the fuel cell itself and the second lights a sign which contains information on the Gencore product. In this configuration it simulates support of critical or emergency loads so that PEM fuel cell power generation can be properly evaluated as a back-up power source. Local electrical and mechanical contractors were hired to provide the required services to support completion of the installation tasks.

Iceland's stated goal of being the first nation in the world to convert entirely to a hydrogen economy makes it an ideal location for this PEM fuel cell demonstration. A very strong team was developed to assist with this project. This team includes interested parties from the Naval Air Station Keflavik, the Icelandic Ministry of Foreign Affairs, the Technological Institute of Iceland, the US Embassy in Iceland and Icelandic New Energy, a world leader in hydrogen fueled vehicles.

The POC for this project is:

Mr. Jon Bjorn Skulason
General Manager
Icelandic New Energy Ltd.
PO Box 8192
128 Reykjavik
Iceland

Bus: (354) 588-0310
Mobile: (354) 863-6510
Bus Fax: (354) 588-0315
E-mail: skulason@newenergy.is
Web Page: http://www.newenergy.is

## Table of Contents

**Proposal – Proton Exchange Membrane (PEM) Fuel Cell Demonstration of Domestically Produced Residential PEM Fuel Cells in Military and Federal Government Facilities**

1.0 Descriptive Title

LOGANEnergy Corporation Small Scale PEM Demonstration Project at the Leif Eriksson Air Terminal at the Keflavik International Airport in Keflavik, Iceland. The installed back-up power fuel cell system provides up to 5kW of back-up +48V DC power while operating on hydrogen fuel.

2.0 Name, Address and Related Company Information

LOGANEnergy Corporation

1080 Holcomb Bridge Road
BLDG 100- 175
Roswell, GA 30076
(770) 650- 6388

DUNS 01-562-6211
CAGE Code 09QC3
TIN 58-2292769

LOGANEnergy Corporation is a private Fuel Cell Energy Services company founded in 1994. LOGAN specializes in planning, developing, and maintaining fuel cell projects. In addition, the company works closely with manufacturers to implement their product commercialization strategies. Over the past decade, LOGAN has analyzed hundreds of fuel cell applications. The company has acquired technical skills and expertise by designing, installing and operating over 70 commercial and small-scale fuel cell projects totaling over 9 megawatts of power. These services have been provided to the Department of Defense, fuel cell manufacturers, utilities, and other commercial customers. Presently, LOGAN supports 40 Phosphoric Acid Fuel Cells (PAFC) and PEM fuel cell projects at 30 locations in 12 states, Puerto Rico in the US and 3 locations within Iceland and the UK.

3.0 Production Capability of the Manufacturer

Plug Power manufactures a line of PEM fuel cell products at its production facility in Latham, NY. The facility produces three lines of PEM products including the 5kW GenSys5C natural gas unit, the GenSys5P Liquid Propane Gas (LPG) unit, and the Gencore 5kWe standby power system. The current facility has the capability of manufacturing 10,000 units annually. Plug Power will support this project by providing remote monitoring, telephonic field support, overnight parts supply, and customer support. These services are intended to enhance the reliability and performance of the unit and achieve the highest possible customer satisfaction. Vincent Cassala is the Plug Power point of contact for this project. His phone number is 518.782.7700 ex1228, and his email address is Vincent_cassala@plugpower.com.

4.0 Principal Investigator(s)

| | | |
|---|---|---|
| Name | Samuel Logan, Jr. | Keith Spitznagel |
| Title | President | Vice President Market Engagement |
| Company | Logan Energy Corp. | Logan Energy Corp. |
| Phone | 770.650.6388 x 101 | 724-449-4668 |
| Fax | 770.650.7317 | 770.650.7317 |
| Email | samlogan@loganenergy.com | kspitznagel@loganenergy.com |

5.0 Authorized Negotiator(s)

| | | |
|---|---|---|
| Name | Samuel Logan, Jr. | Keith Spitznagel |
| Title | President | Vice President Market Engagement |
| Company | Logan Energy Corp. | Logan Energy Corp. |
| Phone | 770.650.6388 x 101 | 724-449-4668 |
| Fax | 770.650.7317 | 770.650.7317 |
| Email | samlogan@loganenergy.com | kspitznagel@loganenergy.com |

6.0 Past Relevant Performance Information

a) Contract: PC25 Fuel Cell Service and Maintenance Contract #X1237022

Merck & Company
Ms. Stephanie Chapman
Merck & Company
Bldg 53 Northside
Linden Ave. Gate
Linden, NJ 07036
(732) 594-1686

Four-year PC25 PM Services Maintenance Agreement.
In November 2002 Merck & Company issued a four-year contract to LOGAN to provide fuel cell service, maintenance and operational support for one PC25C fuel cell installed at their Rahway, NJ plant. During the contract period the power plant has operated at 94% availability.

b) Contract: Plug Power Service and Maintenance Agreement to support one 5kWe GenSys 5C and one 5kWe GenSys 5P PEM power plant at NAS Pawtuxet River, MD.

Plug Power
Mr. Vincent Cassala
968 Albany Shaker Rd.
Latham, NY 12110
(518) 782-7700 ex 1228

c) Contract: A Partners LLC Commercial Fuel Cell Project Design, Installation and 5-year service and maintenance agreement on 600kW UTC PC25 power block.
Contract # A Partners LLC, 12/31/01

Mr. Ron Allison
A Partner LLC
1171 Fulton Mall
Fresno, CA 93721
(559) 233-3262

7.0 Host Facility Information

Keflavik Airport was constructed by the United States during World War II for military purposes and inaugurated on March 24, 1943. In 1946 an agreement was signed between the Icelandic and the US Governments to the effect that all military personnel should leave Iceland and between 1947-1951 the airport was operated by US civilian contractors. On May 5, 1951 following a request from NATO, in which Iceland was already a member since March 1949, a Defense Agreement was signed between Iceland and the United States where the US assumed the defense of Iceland and the areas around the country on behalf of NATO.

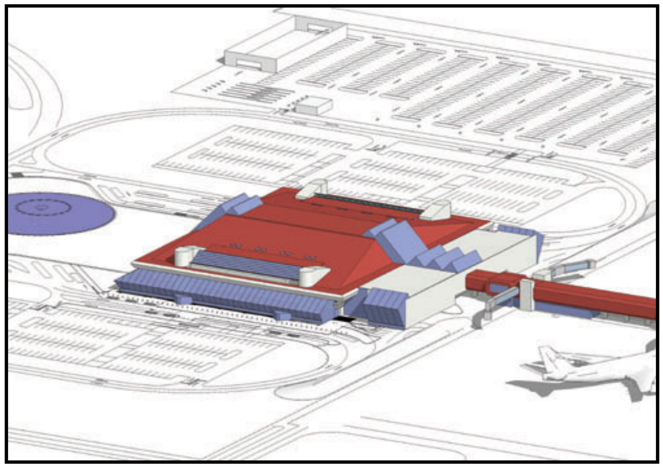

**Figure 1: Leifur Eriksson Air Terminal, Keflavik International Airport**

Since the end of the Cold War the military activity has decreased considerably. The US Navy has a squadron of Lockheed P3 Orion anti-submarine aircraft and the US Air Force McDonnell-Douglas F-15 Eagle fighters; furthermore C-130 Hercules, KC-135 Strato-tanker and Sikorsky 60 rescue helicopters are stationed here.

Today Keflavik Airport is a joint civil and military airport, operated by the Icelandic Civil Aviation Administration and the US Navy. The airport is situated on the Reykjanes peninsula 50 kilometers south-west from Reykjavík the Capital. The airport area is approximately 25 square kilometers. Keflavik Airport is open for business 24 hrs a day, 7 days a week, 52 weeks a year. During the peak season there are about 1,000 civil aviation related jobs on the airport. In 2004 Keflavik Airport handled over 1.6 million passengers.

**Figure 2: Leifur Eriksson Air Terminal, Keflavik International Airport**

The Leifur Eríksson Air Terminal was inaugurated in April 1987 and was initially 24,000 square meters. A 15,000 square meters addition was completed in the spring of 2001.

## 8.0 Fuel Cell Installation

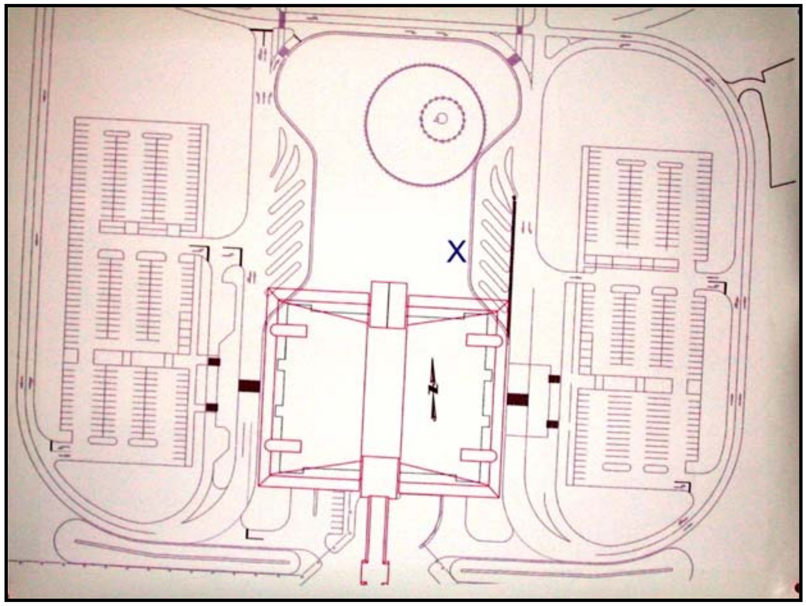


**Figure 3: Fuel Cell Site Location Map**

The fuel cell and chemical energy storage module (CESM) were installed on a poured concrete slab adjacent to Leif Ericson terminal in Keflavik, Iceland. The slab is near a small decorative pond that contains a raised statue in its center (see “X”, Fig. 3). This area is near the taxi cab queue and provides a high level of public visibility for the demonstration project. The fuel cell will provide +48Vdc power to four sets of landscape lights which light up the fuel cell itself as well as a spot light which provide lighting for a fuel cell informational poster. The lights are visible to all visitors entering and leaving the airport via the main access road. Service access to the fuel cell will utilize the driveway to the east of the site.

**Figure 4: Fuel cell & control panel**

Due to the nature of the demonstration, it was necessary to install additional equipment to simulate a DC bus. This equipment includes a small (1500W) 48VDC power supply, a 100 amp contactor, and a programmable electronic timer. This equipment is installed in a rainproof enclosure approximately five meters from the fuel cell (See Fig. 4). Locating the controls in a separate enclosure away from the CESM satisfies the 15 ft requirement as specified by the NFPA. All connections between the fuel cell and the panel are via underground conduit. The fuel cell required two separate conduit runs for power conductors (1 1/2in) and communications (3/4 in). The power for the control circuits and support equipment is provided by a single 20A, 220V branch circuit.

The fuel cell and CESM are installed adjacent to each other on the concrete slab. In this arrangement, the CESM is approximately six inches from the fuel cell. The fuel cell and CESM are anchored to the slab using standard concrete anchors. This is the arrangement recommended by the manufacturer. The CESM and fuel cell are connected using the factory supplied stainless steel hose assembly and sensor wiring harness. The fuel cell and CESM are connected via a common field installed grounding conductor.


**Figure 5: CESM & hydrogen cylinder**

**Figure 6: CESM height extension**

Before the CESM was installed, some modifications were necessary to accommodate the standard hydrogen cylinders used in Iceland. The cylinders are of the European design and are approximately six inches taller that the standard industrial cylinders available in the United States (See Fig. 5). These cylinders also feature an integral valve protector that is not easily removable. The threaded connector used in Iceland is of a different design than the fittings used in the United States. A local machine shop was contracted to fabricate an extension for the bottom of the CESM. The cabinet extension increased the inside height of the storage cabinet by approximately six inches. The CESM was bolted to the extension which had been anchored to the slab (See Fig. 6). Plug Power was able to supply adapters that allowed connection of the European style valve fittings to the existing hydrogen manifold.

Upon completion of the equipment installation, it was necessary to commission the fuel cell. This involves removing factory installed coverings from all fuel cell openings, installing hydrogen cylinders in the CESM, and performing the initial startup. During the startup, additional checks are performed including fuel pressure check, leak check, and overall system operation. Figure-7 shows the completed Gencore installation.

**Figure 7: Finished Gencore Installation**

9.0 Electrical System

The Plug Power Gencore is designed for use in the telecommunications industry. It is intended for direct current (DC) applications and is normally installed in parallel with a DC rectifier and accompanying lead-acid battery bank. By design, the Gencore is always connected to the customer bus and continually monitors the voltage of the primary supply. If the customer bus voltage drops below a user defined setpoint, the Gencore will start automatically and provide reliable back up power for the customer application. When running, the Gencore matches its current output to the required load and runs at a voltage slightly below (0.5V) the customer setpoint. Once the customer DC bus returns, the fuel cell senses the corresponding voltage rise and returns to standby mode. The available runtime depends on the average output power although the Gencore is capable of providing ten hours of runtime at 5.0 kW using a bank of six industry standard hydrogen cylinders. During standby, the Gencore draws a nominal amount of power from the bus to maintain cabinet temperature and controller operation. The power consumption can vary from 50W to 900W depending on ambient temperature.

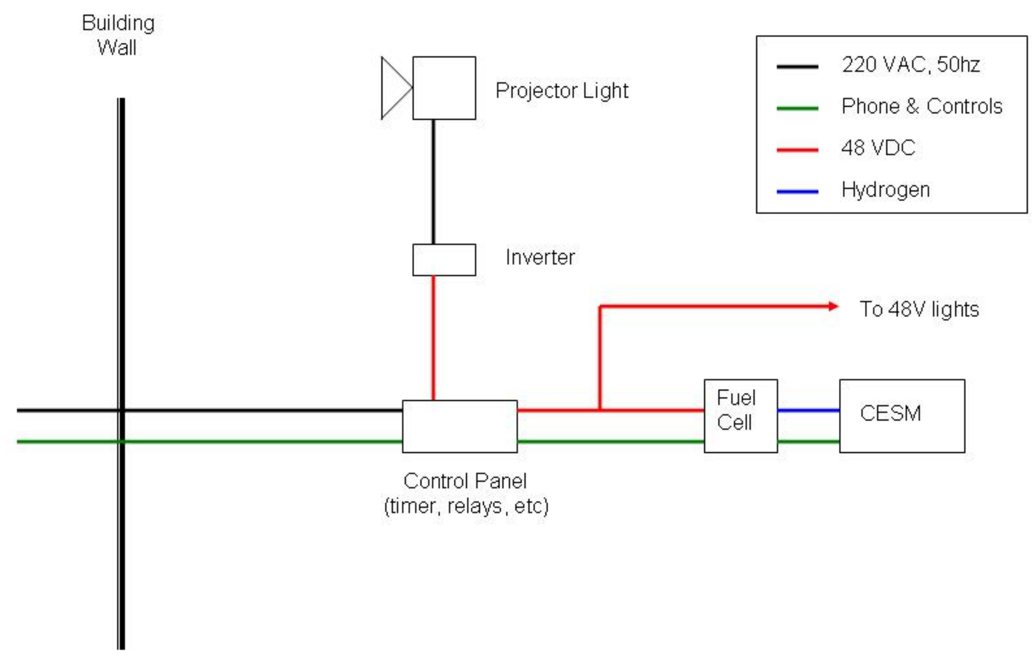


Fig. 8 **US NAS Keflavik Block Diagram**

In order to test the operation of the unit, LOGANEnergy installed a test panel to simulate the DC bus. This panel consists of a 48 VDC Lambda power supply, a programmable cycle timer, and two relays. The test load consists of a combination of 24VDC landscape lights and a high wattage spot light. The dual bulb landscape lights were series connected in order to utilize the 48V output of the fuel cell. An inverter was required to provide the AC output necessary to energize the projector light. The lighting circuits can be operated selectively using a breaker panel located on the back side of the control box.

During the test cycle, the timer simulates a DC bus failure by disabling the output of the power supply (relay 1). At the same time, the timer closes the load relay (relay 2) and energizes the lighting circuits. Once the voltage drops below the predefined setpoint, the fuel cell starts and runs the load for a specified time. In this demonstration, the timer is programmed to initiate two test cycles a day for a period of twenty five minutes each. The timer is configured such that the lights are illuminated during the airport's peak arrival and departure times. A simplified block diagram of the system is provided in Figure 8.

## 10.0 Thermal Recovery

Not applicable.

## 11.0 Data Acquisition

The GenCore controller will record and store operating data including the number of automatic starts, fuel cell operating hours, and kWh provided to the DC load. The Gencore also receives input from pressure transducers inside the CESM Storage Module. These pressure transducers allow daily fuel consumption to be calculated remotely using the fuel cell modem. The required data will be downloaded regularly and used to compile a running database that documents the performance of the fuel cell.

## 12.0 Fuel Supply

Fuel is supplied to the Gencore via industrial hydrogen cylinders. In Iceland, the local distributor is AGA (Linde). The optional CESM hydrogen storage module that is offered by Plug Power accepts six, industry standard, 50 litre hydrogen cylinders. The cylinders are divided into two banks of three, and either bank can be replenished without interrupting the operation of the system. The CESM comes equipped with an automatic changeover valve that automatically switches cylinder banks once one has been depleted. The CESM includes analog pressure transducers that allow the Gencore to display fuel level through pressure measurement. Fuel usage is calculated manually using the physical relationship between pressure, temperature, and volume.

13.0 Installation Costs

**NAS Keflavik – Keflavik International Airport PEM Demonstration Project**

| | | |
|---|---|---|
| 1) | Water (per 1,000 gallons) | N/A |
| 2) | Utility (per KWH) | N/A |
| 3) | Bottled Hydrogen ( per SCF) | $ 0.510 |

| **First Cost** | **Budgeted** | **Actual** | **Variance** |
|---|---|---|---|
| Plug Power 5 kW Gencore | $ 20,000 | $ 14,915 | **$ (5,085)** |
| Product Training - Gencore (2 people) | $ 5,000 | $ 5,000 | **$ -** |
| Shipping | $ 5,200 | $ 3,992 | **$ (1,208)** |
| Installation electrical | $ 6,770 | $ 5,074 | **$ (1,696)** |
| Installation mechanical & thermal | $ 6,460 | $ 7,023 | **$ 563** |
| Instrumentation, Data Package | $ 1,500 | $ 1,494 | **$ (6)** |
| Site Prep, labor materials | $ 2,500 | $ 3,225 | **$ 725** |
| Technical Supervision/Start-up | $ 3,500 | $ 3,500 | **$ -** |
| Installation Travel & Per Diem | $ 11,967 | $ 18,154 | **$ 6,187** |
| Total | **$ 62,897** | **$ 62,377** | **$ (520)** |

| **Annual Operating Expenses** | **Budgeted** | **Actual** | **$/Min** | **Budgeted** | **Actual** | **Variance** |
|---|---|---|---|---|---|---|
| Bottled Hydrogen, Scf/min @ 1.0kW | 0.4586 | 0.5517 | $ 0.234 | $ 3,406 | $ 4,097 | $ 691 |
| **Hydrogen Cost/kWh** | | | **$ 14.03** | | | |

| **Economic Summary** | **Budgeted** | **Actual** | **Variance** |
|---|---|---|---|
| Forecast Annual kWH | 303 | 288 | -15.3 |
| Annual Cost of Operating Power Plant kWH | $ 11.23 | $ 14.23 | $ 3.00 |
| Credit Annual Thermal Recovery kWH | N/A | N/A | N/A |
| Project Net Operating Cost kWH | $ 11.23 | $ 14.23 | $ 3.00 |
| Displaced Utility cost kWH | N/A | N/A | N/A |
| **Energy Savings (Increase)** | N/A | N/A | N/A |
| **Annual Energy Savings (Increase)** | N/A | N/A | N/A |

## 14.0 Acceptance Test

The acceptance test included verifying all operational and safety aspects of the installation. In general, the test includes observing the operation of the Gencore through several automatic test cycles. A satisfactory test includes completion of the following events:

1) – the Gencore detected a drop in the DC bus voltage

2) – the Gencore initiated a “Low Bus Start”

3) – the bus voltage stabilized and remained at the bus setpoint with the load applied

4) – when the bus returned the Gencore detected the availability of the bus

5) – the fuel cell demonstrated a controlled shutdown

6) – the system reinitialized to the “System Ready” state

During the initial acceptance test, there was a problem with the operating software installed on the Gencore controller. After each run cycle, the Gencore failed to reinitialize the internal heaters that serve to maintain the cabinet temperature. As a result, the heaters had to be initialized manually after each test cycle. The manufacture was able to do this remotely using the installed modem. This manual intervention was performed twice daily during the first few weeks of the project. Plug Power was notified of the problem and began working on a software revision.

In January of 2006, Plug Power released new software that corrected the problem with the heater circuit. On January 24, 2006, the software was installed on the Gencore. Once the new software was installed the Gencore successfully passed all aspects of the acceptance test and was entered into service on January 25th, 2006.

## 15.0 Appendix

1.0 Gencore 5B48 Product Specification Sheet

plug power

### Rugged, reliable design.

**Flexible**

**Proton Exchange Membrane (PEM) Fuel Cell Stack** – proprietary fuel cell design delivers efficient, clean, quiet DC power. Integrated cell voltage monitoring provides continuous feedback for optimal fuel cell performance.

**DC Power Conditioning** – GenCore systems offer either -48Vdc or +48Vdc power conditioning to meet the needs of wireless and wireline providers.

**Reliable**

**Electrical Energy Storage** – maintenance-free system provides immediate response to power interruptions.

**Fuel Storage System** – available in a variety of forms, hydrogen fuel storage is scalable to meet site and provider specific needs.

**Robust**

**Thermal Management System** – freeze-tolerant design is compliant with Telcordia NEBS standards, including operation from -40C to 46C.

**Insulated Cabinet** – rugged design is finished with a high-quality paint process that protects the exterior finish.

GenCore.

| PRODUCT CHARACTERISTICS | | GENCORE 5B |
|---|---|---|
| Performance | Rated Net Output[1] | 0 to 5,000 W |
| | Adjustable Voltage | +46 to -56 Vdc (+48) |
| | Operating Voltage Range | +42 to +60 Vdc |
| | Operating Current Range | 0 to 109 Amps |
| Fuel | Gaseous Hydrogen | 99.95% Dry |
| | Supply Pressure | 80 psig |
| | Fuel Consumption | 40 slm at 3,000 W |
| | | 75 slm at 5,000 W |
| Operation | Ambient Temperature | -40 C to 46 C |
| | Relative Humidity | 0% to 95% Non condensing |
| | Altitude | -197 ft to 6,000 ft |
| Physical[2] | Dimensions | 44" H x 26" W x 24" D |
| | Weight | 500 Lbs |
| Safety | Compliance | FCC Class A |
| | | ANSI Z21.83 |
| | | UL Listed |
| | | Telcordia GR 63, 78, 487, 1089 |
| Emissions | Water | Maximum 1.75 Liters per hour |
| | CO, CO2, NOx, SO2 | <1 ppm |
| | Audible Noise | 60 dba @ 1m |
| Sensors[3] | Gas Hazard Detection | Standard |
| Control | Microprocessor | Standard |
| | 2 LED Panel | Standard |
| | Low Fuel Alarm | Standard |
| | Communications[4] | RS-232 |
| | | Digital Interface |

[1] Rating applies for altitudes up to 1,000 ft. Beyond this, total power available will decrease 1.5% per 1,000 ft.
[2] Excludes fuel storage. Optional fuel module (shown above) is 44" H x 26" W x 24" D.
[3] Optional sensors are available to detect: Pad shear, water intrusion and tampering.
[4] Optional communications include modem or ethernet.

Specifications subject to change without notice.

PLUG POWER INC.
968 Albany Shaker Road
Latham, New York 12110
Phone: +1.518.782.7700
Fax: +1.518.782.9060
www.plugpower.com

2.0 Operating Data through June of 2006

- Runtime = 7.0 months
- kWhr generated = 154
- Requested starts = 418
- Actual starts = 385
- Calc. availability = 92.1%
- Calc. H2 consumption = 15.5 slm